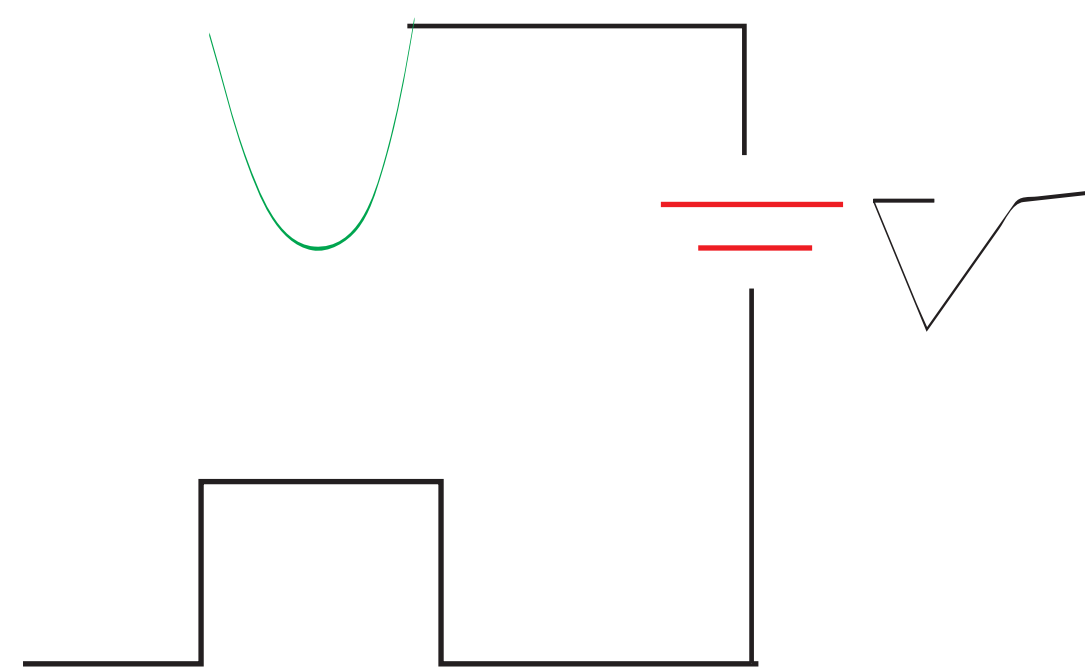


# Self-organized growth of Pb/Si(111) at low temperatures

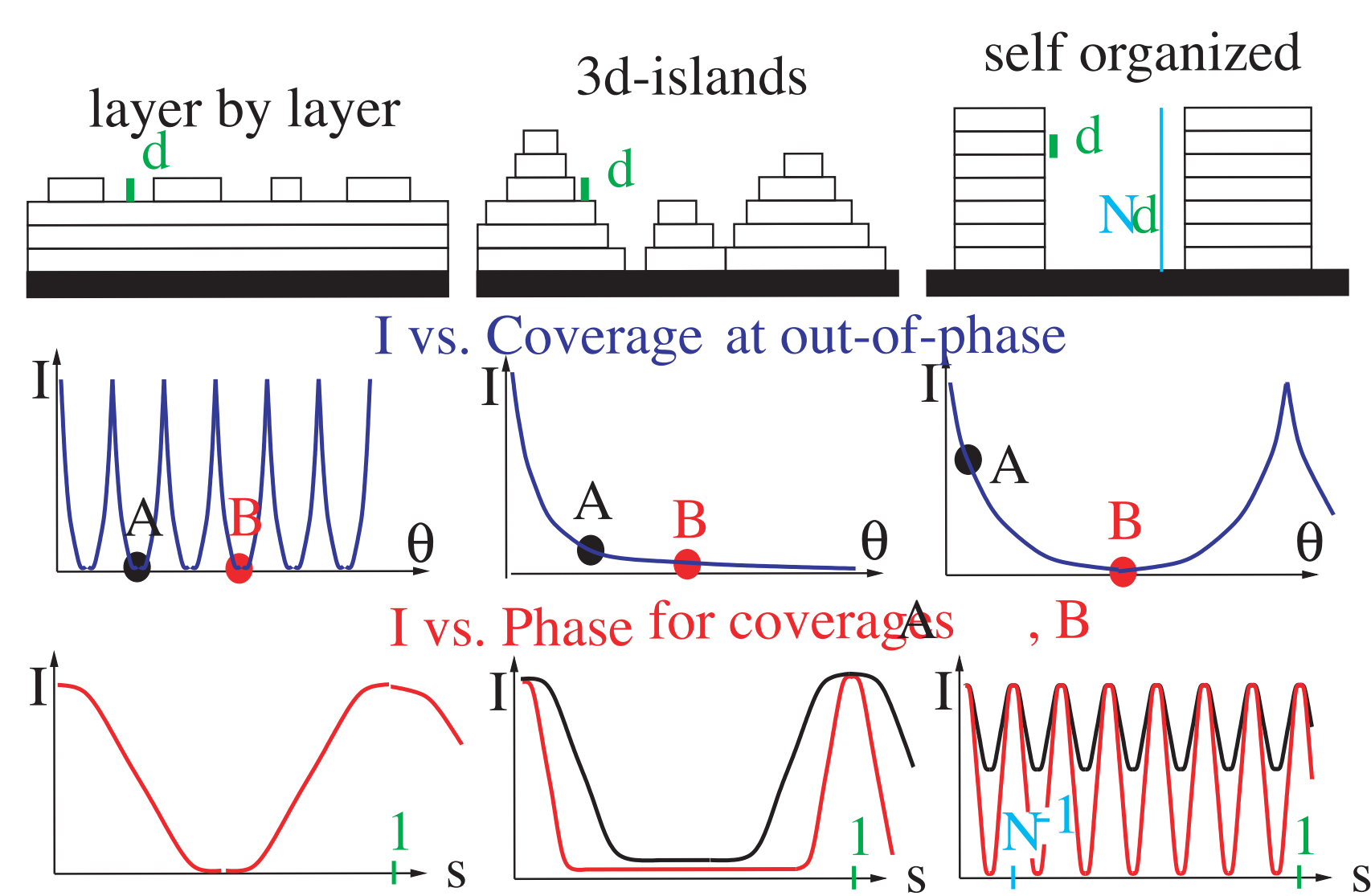
M. Hupalo, V. Yeh, L. Berbil-Bautista, M. C. Tringides

Goal: To grow atomic-scale structures of uniform size and geometry with control of their dimensions. Normally growth is either layer-by-layer or 3-dimensional, with single steps separating different levels  
Result: For Pb/Si(111) we have observed unexpectedly that islands of uniform height and similar geometry (ie. flat tops and steep edges) can be grown at low temperatures.

## Scanning-Tunneling Microscope



Topography or I-V spectroscopy

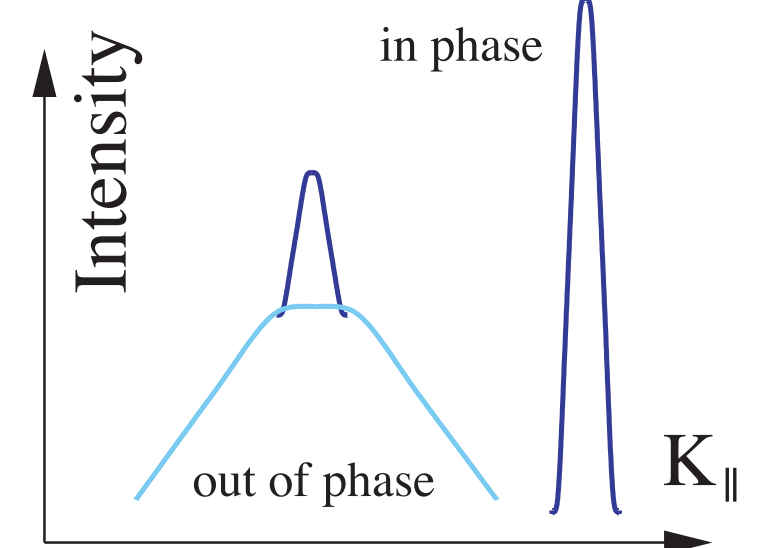
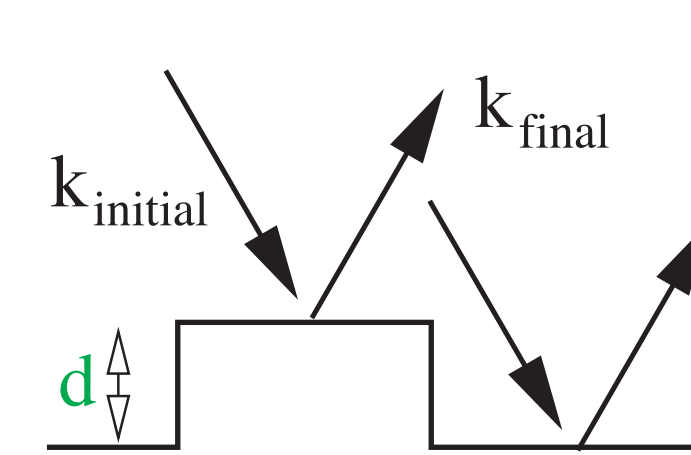


Growth modes  
Observed during the epitaxial growth of a film

## Spot Profile Analysis LEED

$$K = k_{\text{initial}} - k_{\text{final}} \\ = K_{\parallel} + K_{\perp}$$

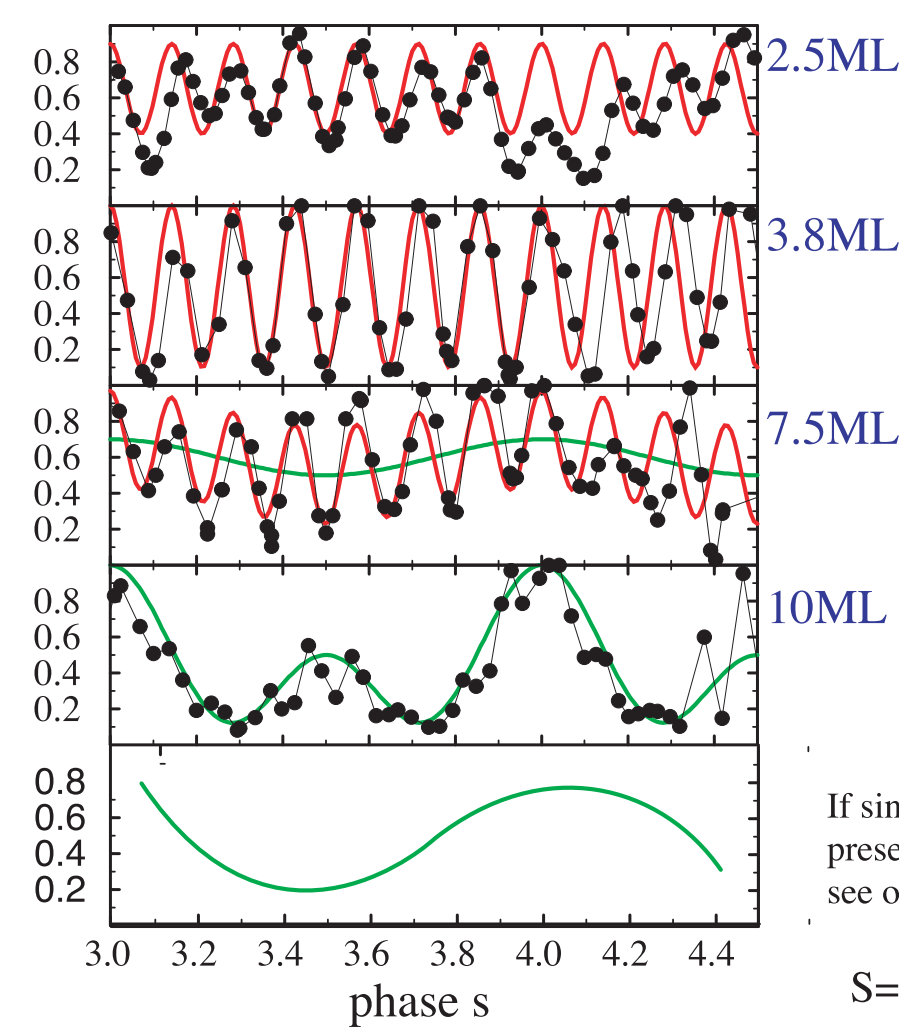
$$s = K_{\perp} d / (2\pi) \\ I = I_C / (I_C + I_S)$$



$$s = K_{\perp} / (2\pi/d) \\ \text{if } s = 0, 1, 2, 3, 4, \dots \text{ in-phase} \\ \text{if } s = 1/2, 3/2, 5/2, \dots \text{ out-of-phase}$$

## Intensity oscillations with phase

7-fold periodicity corresponds to 7-step islands.

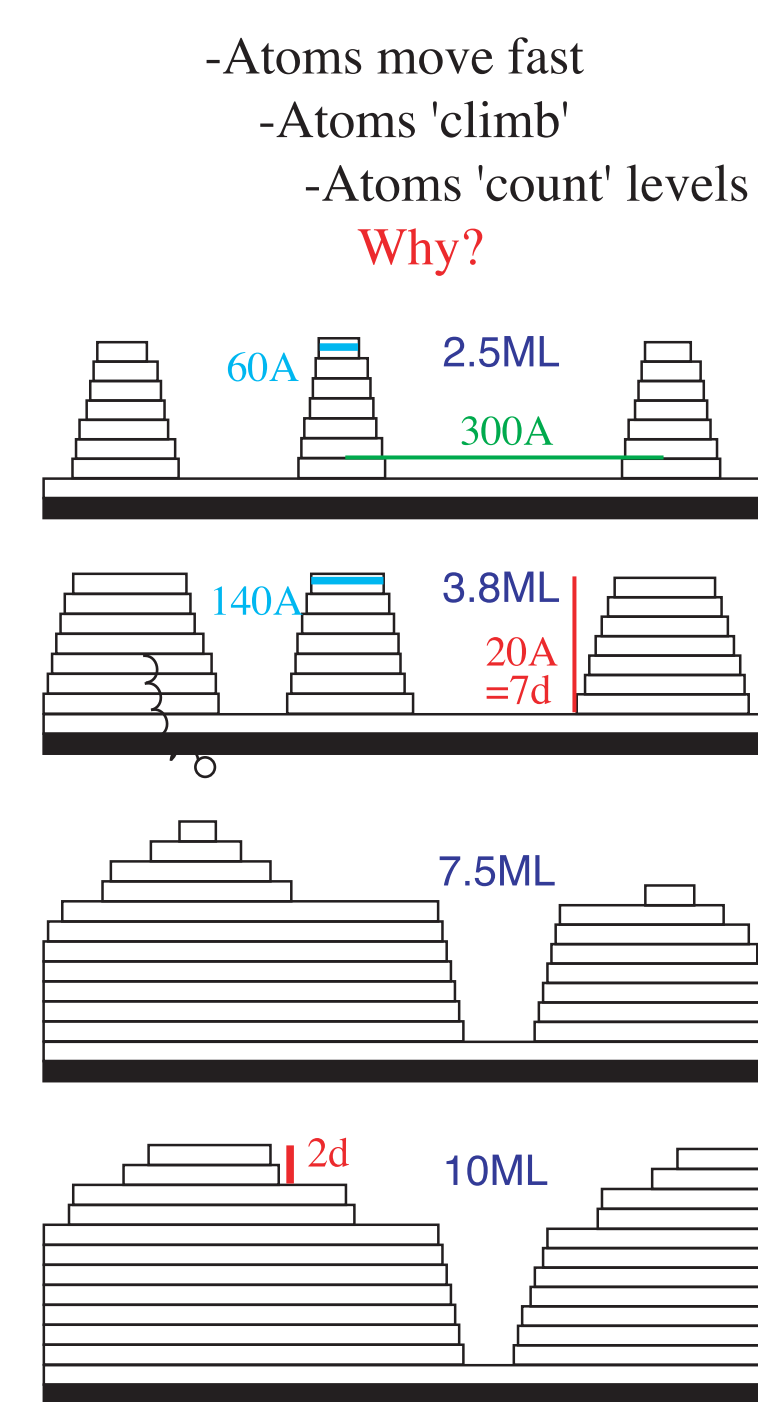


$$S = \frac{K}{(2\pi/d)}$$

Budde et. al. Phys. Rev. B Rapid Comm. B61 10602 (2000)

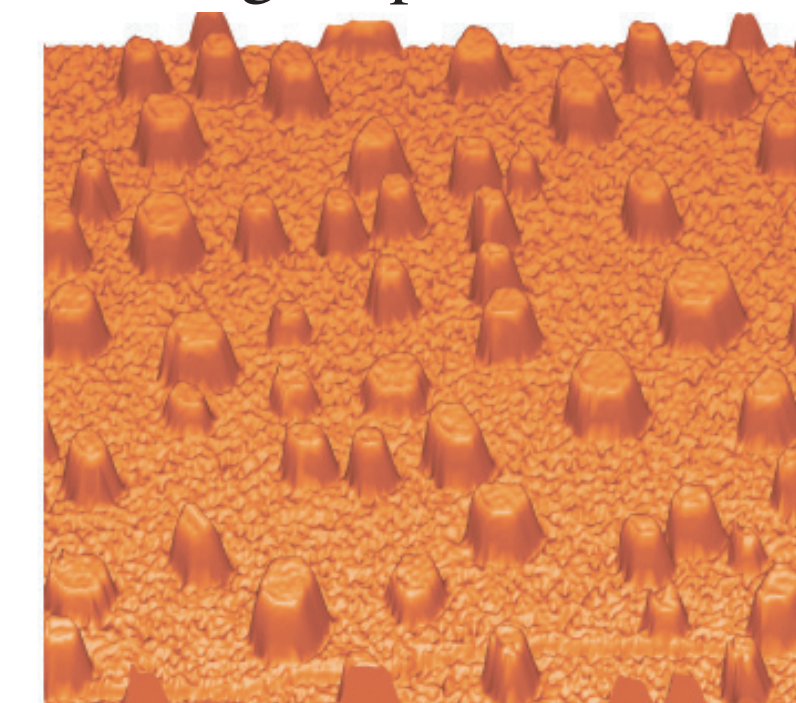
Pb/Si(111) - 7x7

The presence of 7-fold oscillations shows that 7-step islands form on the surface. Since there is only one periodic component, the islands are steep and have flat tops. A model based on the diffraction results is shown to the right. These diffraction results are fully confirmed with STM which show the formation of predominantly 7-step islands. After the film is completed ( $\theta=7.5\text{ML}$ ) single and double steps are observed.

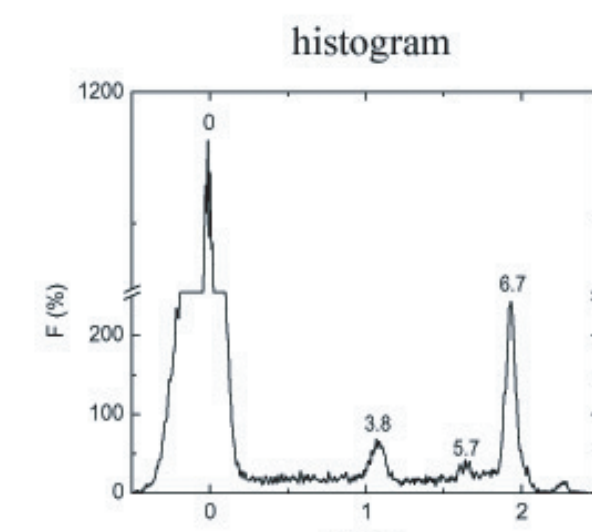


7-Step islands are grown for  $\theta=4\text{ML}$   $T=200\text{K}$

Average island size of 12nm and average separation is 30nm

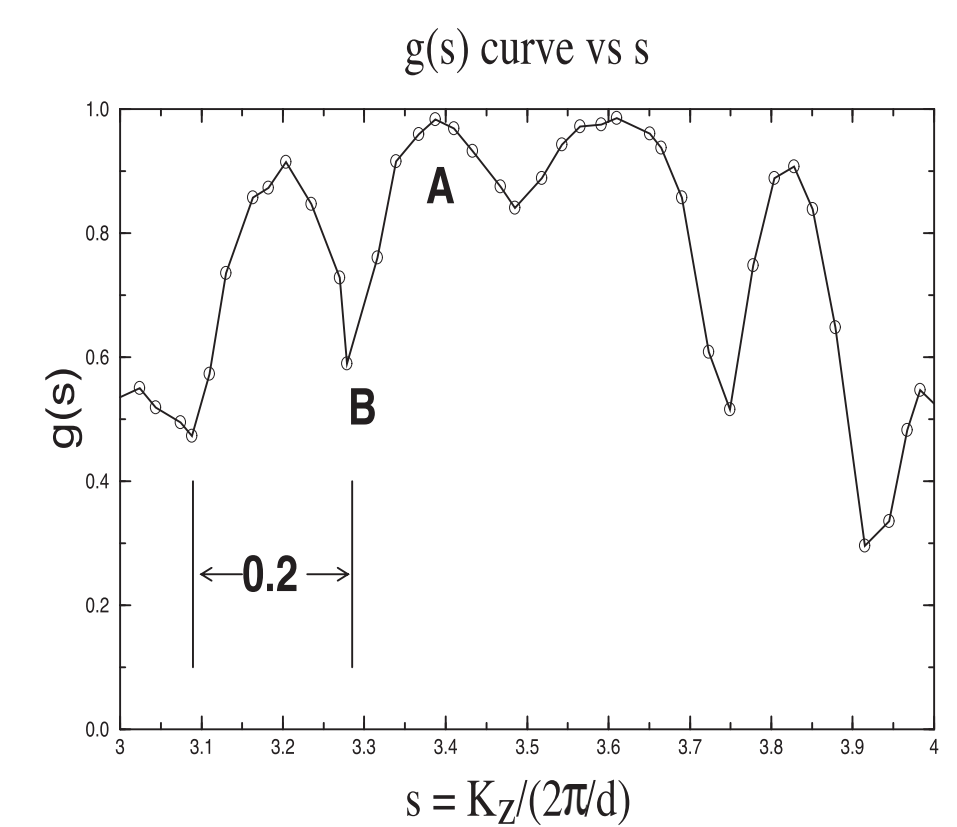
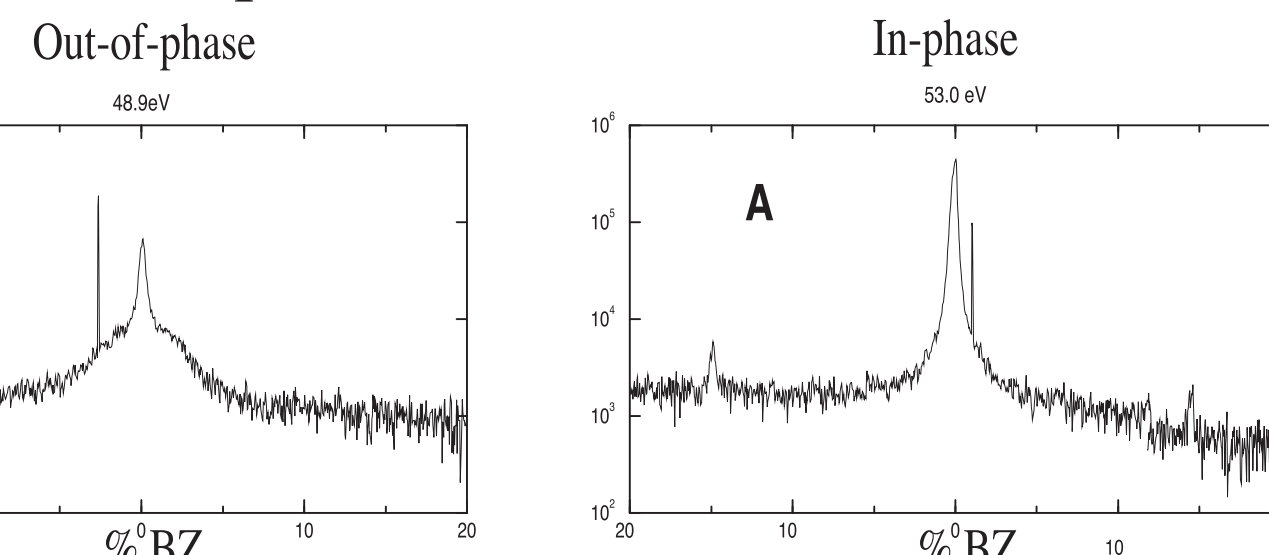


$\theta=3\text{ML}$   
 $T=192\text{K}$   
 $200 \times 200 \text{nm}^2$



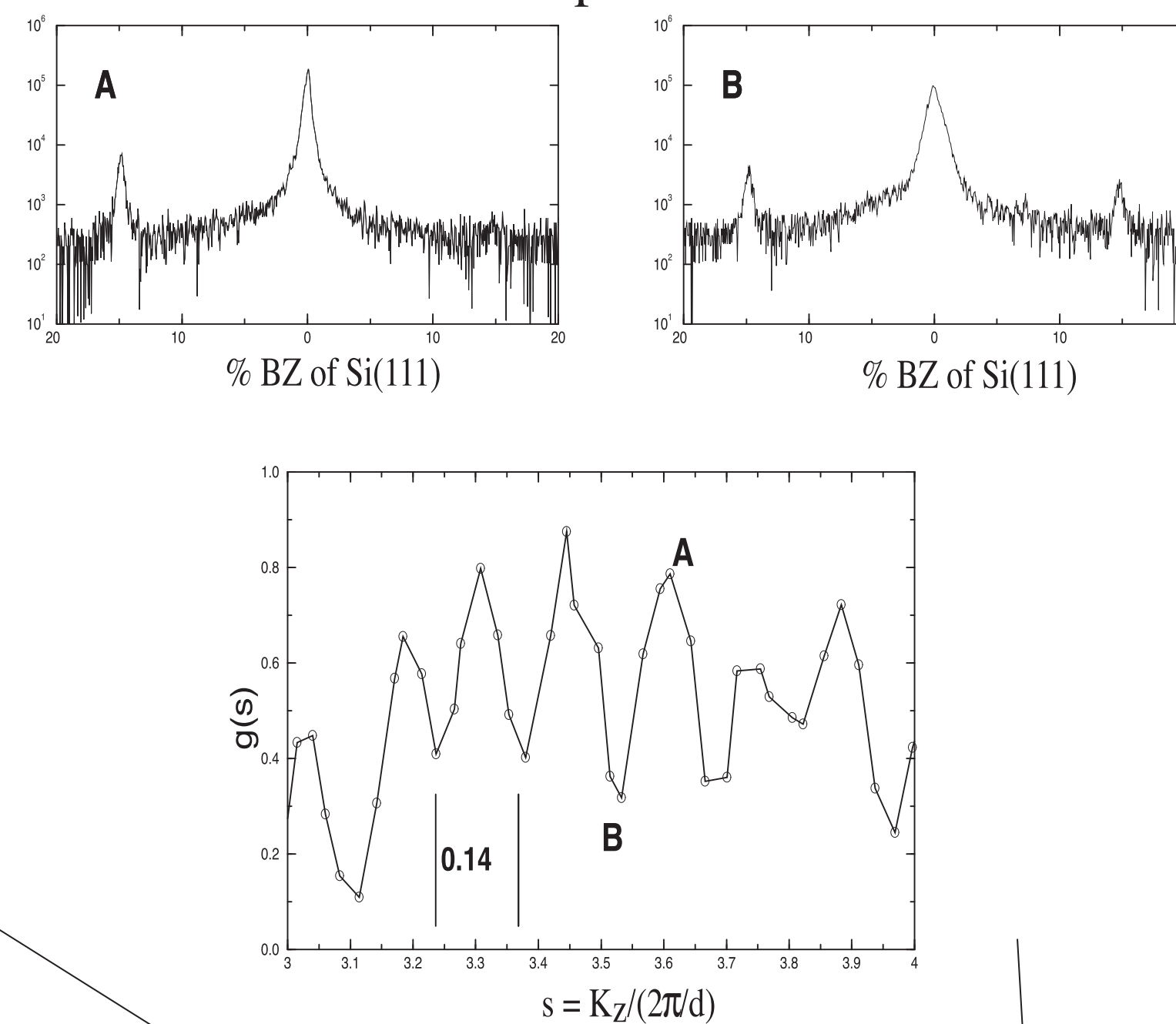
Island height distribution

## 5-step islands $\theta=4.9\text{ML}$ $T=132\text{K}$

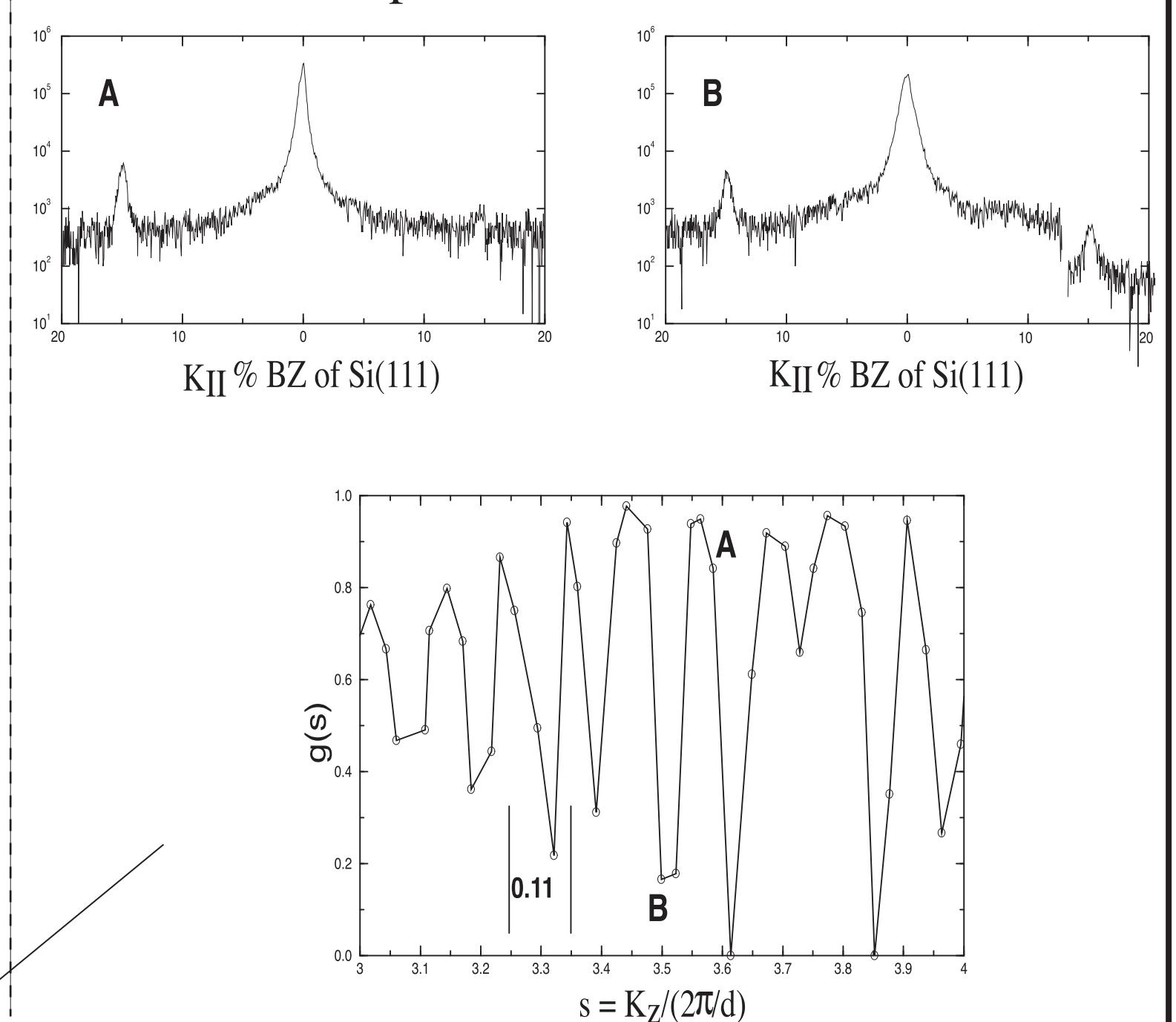


## How does the growth depend on the growth parameters? T, $\theta$

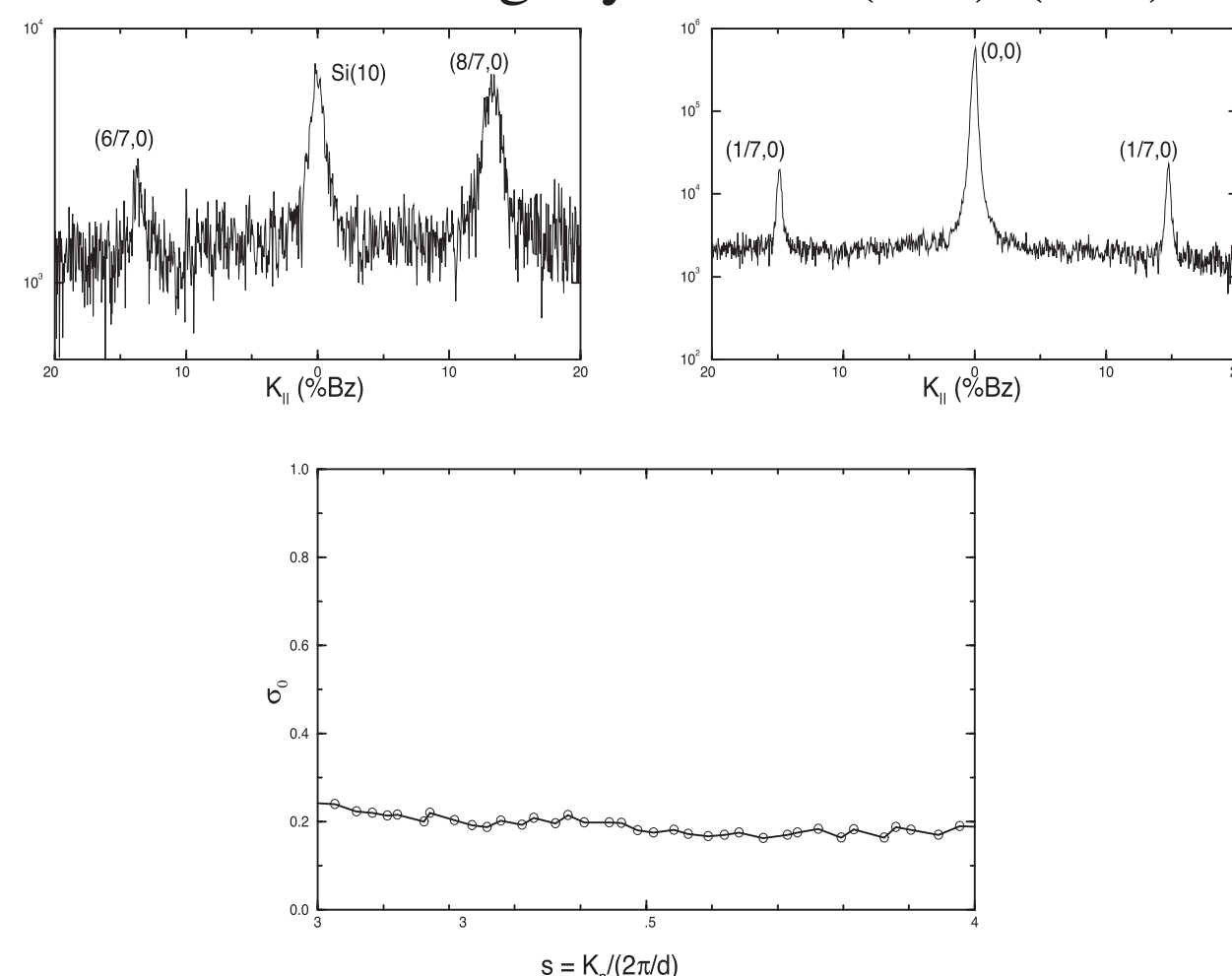
### 7-step islands $\theta=4\text{ML}$ $T=190\text{K}$



### 9-step islands $\theta=5\text{ML}$ $T=205\text{K}$



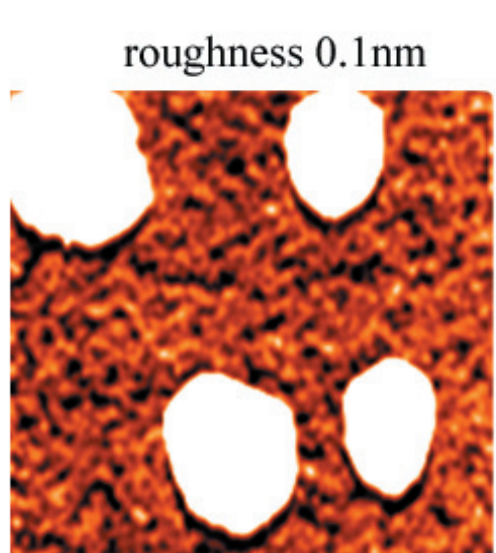
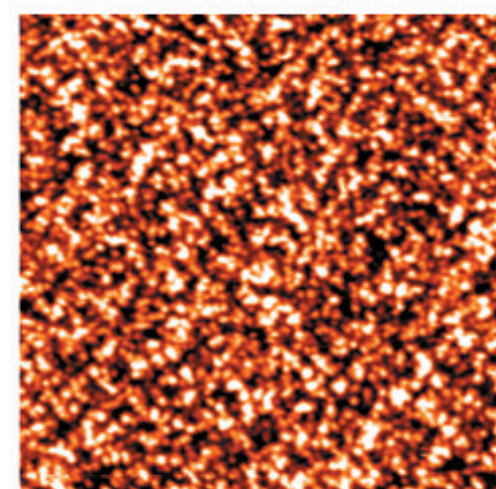
## Pb Wetting layer on Si(111)-(7x7)



$\theta=2\text{ML}$   $T=129\text{K}$

- very smooth wetting layer
- the (7x7) periodicity is preserved
- strain is removed by the wetting layer

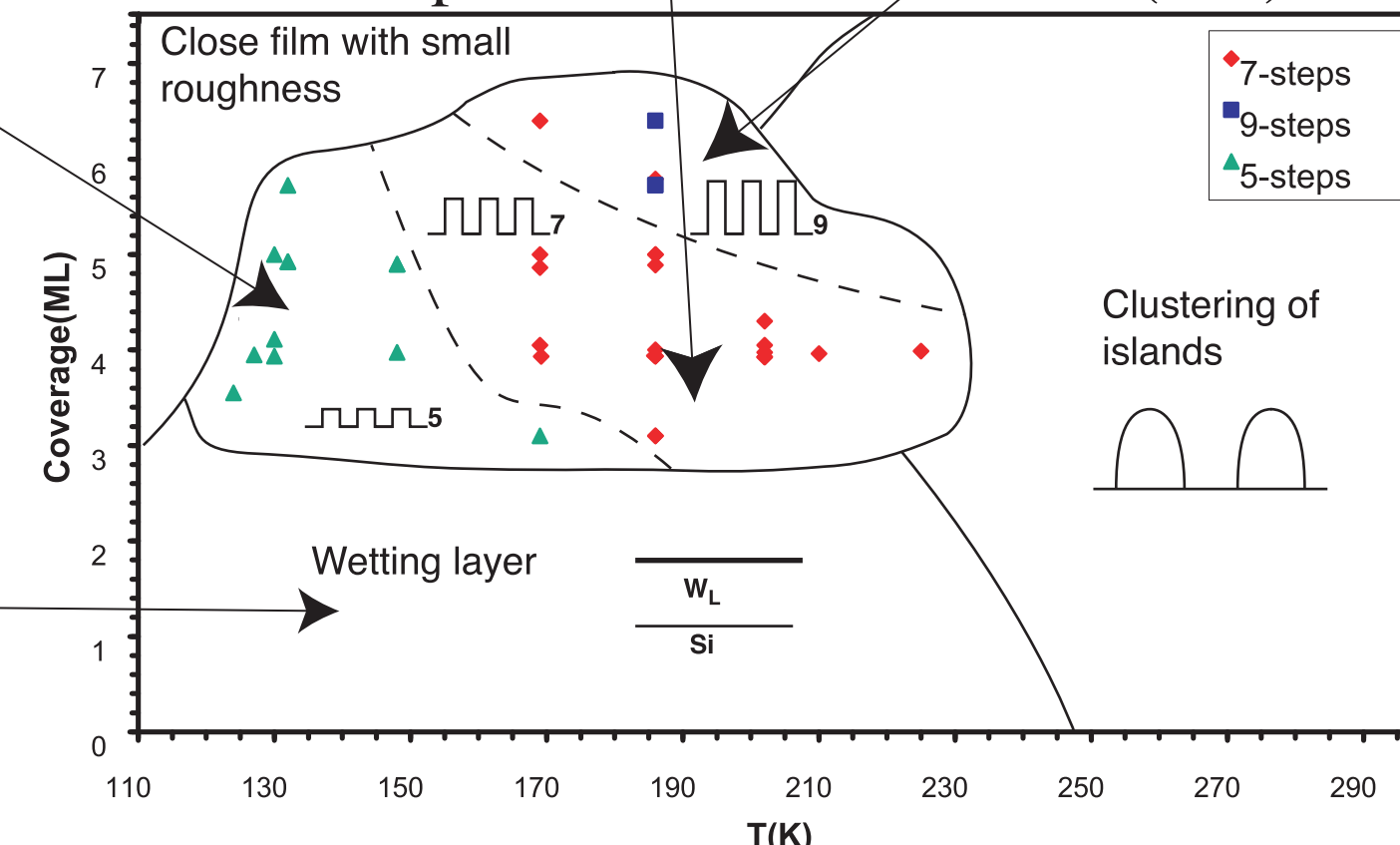
## Si(111) 7x7 surface roughness 0.07nm



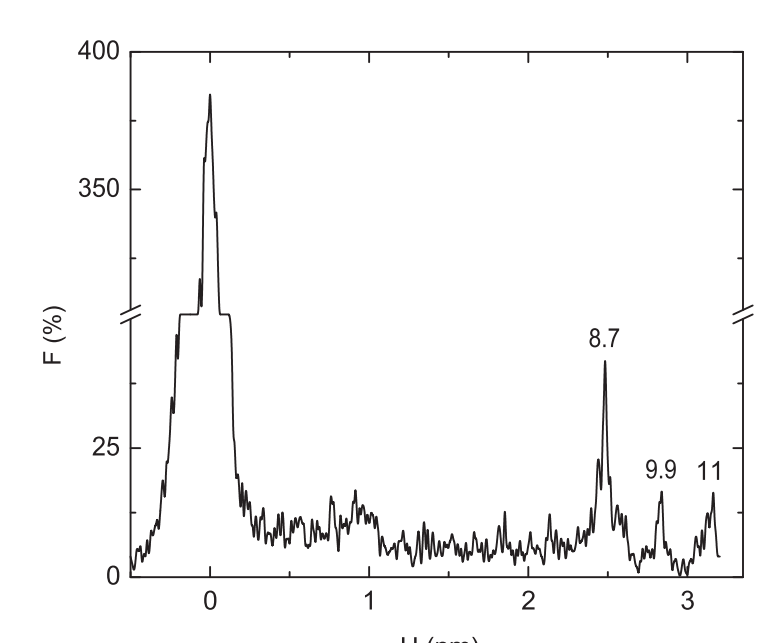
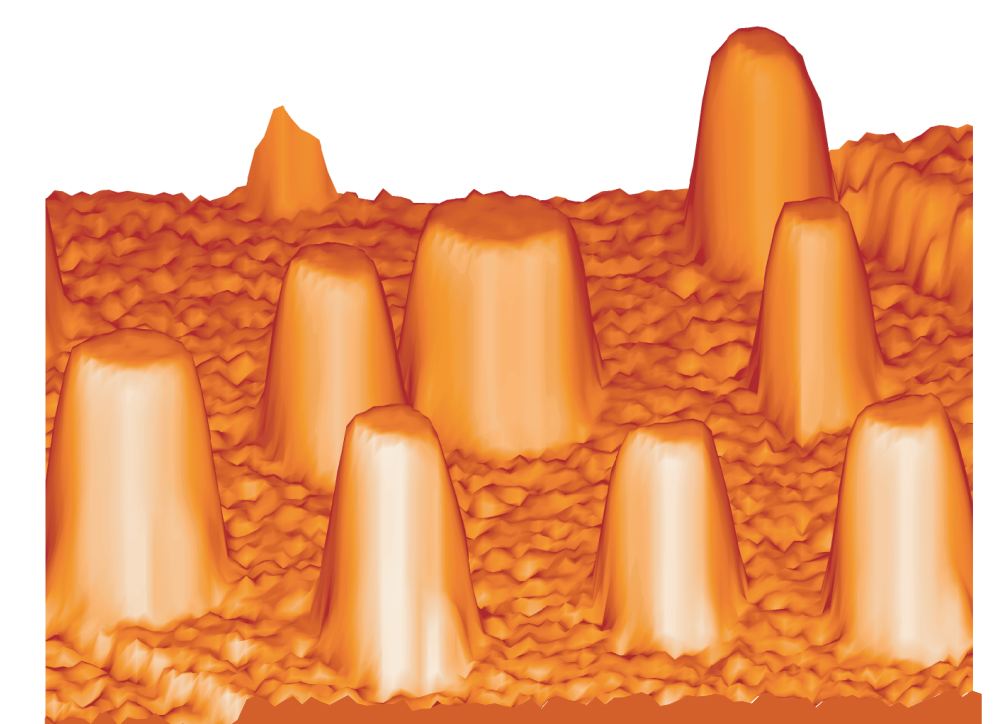
$\theta=2\text{ML}$   
 $T=133\text{K}$   
 $50 \times 50 \text{nm}^2$

$\theta=3\text{ML}$   
 $T=192\text{K}$   
 $50 \times 50 \text{nm}^2$

## Low Temperature Growth of Pb/Si(111)



- As deduced with diffraction and STM uniform height islands with height differing by 2d can be selected by choosing the suitable growth condition of T,  $\theta$ . Lower heights are preferred at low temperature or coverage as shown in the kinetic phase diagram.



Island height distribution